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Physical Model for Coastal Inlet Entrance Studies

by William C. Seabergh

PURPOSE: The Coastal Engineering Technical Note herein provides information about the potential use of a physical model facility dedicated to the study of inlets and equipped to represent the most significant physical processes at and around inlets.

BACKGROUND: An inlet is a region connecting two or more large bodies of water by a relatively short and narrow channel. The water bodies may be an ocean and lagoon, a large lake and a bay, or a river entering a sea or lake. Many processes at inlets can be examined in a thorough and efficient manner in a dedicated inlet physical model.

FACILITIES: As part of the Coastal Inlets Research Program, an idealized inlet was constructed in a 46-m- (150-ft-) wide by 99-m- (325-ft-) long concrete basin with 0.6-m- (2-ft-) high walls. The approach was to design an inlet with simplified bathymetry and fairly steep beach slopes so that additional features (such as an ebb shoal) can easily be added. Also, it was anticipated that a fine sand serve as both a tracer and as a fully mobile bed that can be placed over the concrete bottom in a thick veneer. A 1:50 undistorted scale was assumed to determine reasonable inlet dimensions to model. However, other scales can easily be assumed to accommodate the study of specific processes because of the simplified bathymetry in the model. Also, the bathymetry can be remolded in the inlet entrance area to the more complex bathymetry of an actual inlet, either in fixed bed (concrete) or movable bed (sand). Ebb- and flood-shoal areas can also be modified to represent more complex bathymetries.

Figure 1 shows the basin area of the Idealized Inlet Model Facility. The ocean-side parallel contours were an equilibrium profile according to the equation from Dean (1977), $h = Ax^{0.67}$, where h is depth, x is distance offshore, and A is determined by sediment characteristics. A value of $A = 0.24 \text{ ft}^{1/3}$ was taken, as it represented a relatively steep beach. The contoured ocean beach slope extends to the 18.3-cm (0.6-ft) mean low water (mlw) depth (or 9.1-m (30-ft) depth if scaled by 1:50) and is linearly transitioned to the basin floor at a depth of 30.4 cm (1.0 ft) (or 15.2-m (50-ft) depth when scaled by 1:50). The inlet throat region converges to a depth of 15.2 cm (or when scaled to 1:50, 7.6 m (25 ft)) relative to a mlw datum.

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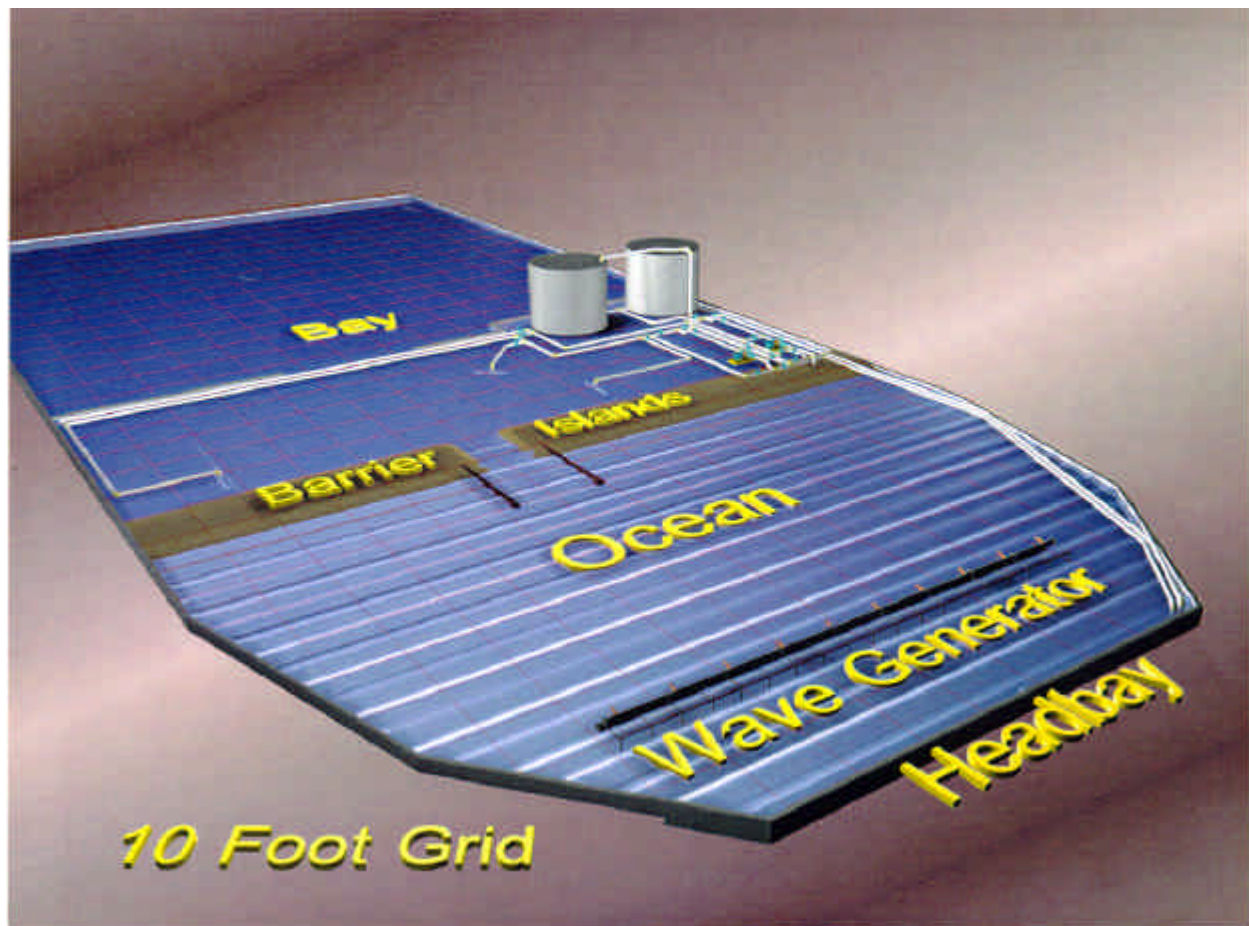


Figure 1. Oblique view of inlet model research facility

The minimum width is 244 cm across the inlet between mlw contours (or when scaled by 1:50, represents a width of 122 m (400 ft)). Figure 2 shows the inlet throat and entrance channel with parallel jetties that have a spacing of 3.66 m (12.0 ft) and extend 5.5 m (18 ft) offshore.

Based on Froude's model law (Hughes 1993), which requires equivalence of the expression $v/(gh)^{1/2}$ in the model and prototype (with v = velocity, g = gravitational acceleration, and h = a depth or length scale), and the linear scale of 1:50, the model-prototype relations in Table 1 were derived. Dimensions are in terms of length (L) and time (T). Other scales may be assumed for the bathymetry, so that different scaling relationships would apply than listed in Table 1.

The Idealized Inlet Facility is connected to a large sump (volume of 1.98×10^6 L (523,000 gal)) for water exchange so that tides may be produced in the ocean of the facility to drive tidal currents into and out of the inlet bay. A constant inflow is introduced from the sump into the model ocean while a "rolling" gate either reduces or increases flow area over an exit pipe into the sump, which causes ocean rise or fall, respectively. The rolling gate is regulated by a controller connected to a feedback loop comparing actual with desired water level. The two circular shapes in the upper left corner of Figure 1 are storage tanks, each holding 182,000 L (48,000 gal) of water. The tanks enable simulation of a much larger bay area by storing flood tide water and



Figure 2. Idealized inlet entrance channel

Table 1 Model-Prototype Scale Relations		
Characteristic	Dimension	Model-Prototype Scale Relation
Length	L	$L_r = 1:50$
Area	L^2	$A_r = L_r^2 = 1:2,500$
Volume	L^3	$V_r = L_r^3 = 1:125,000$
Time (tidal and short wave period)	T	$T_r = L_r^{1/2} = 1:7.07$
Velocity	L/T	$V_r = L_r/T_r = 1:7.07$

releasing it back to the bay to flow to the ocean during ebb flow. Pumps and control valves associated with this procedure are located adjacent to the storage tanks.

A steady-state flow may also be created for representing ebbing or flooding currents. The piping system is shown in Figure 1. Water is either collected (flood flow) or distributed (ebb flow)

through a system of manifolds in the bay that may be adjusted for one, two, or three bay channels or a uniform flow across the bay. Water is either released (flood flow) or taken from (ebb flow) the ocean headbay to complete the circulation energized by the pumps located in the right center region of Figure 1.

An 80-ft-long, unidirectional wave generator (see Figure 1) installed in the ocean produces either irregular or monochromatic waves. Unscaled wave periods can be varied from 0.5 to about 3 sec, and long-crested wave heights to 10 cm can be generated (at the generator location, before shoaling and refraction). Incident wave direction can be varied for specific experiments by moving the generator to different locations.

INSTRUMENTATION AND CALIBRATION:

Wave height and period data are collected on electrical capacitance wave gauges that are calibrated daily with a computer-controlled procedure incorporating a least-square fit of measurements at 11 steps. This technique averages 21 voltage samples per gauge and minimizes distortions introduced by slack in the gear drives and hysteresis in the sensors. Typical calibration errors are less than 1 percent of full scale for the capacitance wave gauges. Wave signal generation and data acquisition are controlled by computer. Wave data are evaluated with a special analysis package for the frequency and time domains.

Water-velocity data are collected with Sontek 2D Acoustic Doppler Velocimeter (ADV) with a side-looking probe that is oriented to collect two components of velocity in a horizontal plane. This model velocimeter is designed to work in the relatively shallow waters of an inlet. Samples are collected at 10 Hz, though the instrument makes 250 pings per second and averages for each output sample. Accuracy is ± 0.5 percent of the measured velocity, with resolution of 0.1 mm/sec and threshold of 0.1 cm/sec. The probe samples a 0.25-cm^3 volume located 5 cm from the sensor heads. A gauge rack holds both the wave and current sensors, which can be moved to collect data without interference in the processes to be measured.

Water-surface elevations are measured with a “bubbler system,” where small-diameter plastic tubing is mounted and placed at a given elevation below the water level at various locations throughout the inlet region. A constant pressure is applied, and air is bubbled out of the tubes at a bubble rate of 3 Hz. Pressures are measured with high precision, differential pressure transducers and converted to elevation (± 0.015 cm). The pressures are sampled at a rate of 1 Hz and include sampling of a calibration array of bubble tubes set at different elevations in a still-water pit (located in the model facility).

EXAMPLES OF STUDIES:

The inlet facility is adaptable for a variety of studies. In its existing “idealized” state, it can be used to study basic concepts in a generic manner. For example, if changes were proposed for the location-orientation of channels converging from the bay into the main inlet channel exiting to the ocean, measurements to determine change in flow distribution in the inlet gorge and ebb channel could be quickly performed. In its sedimentary mode, i.e., with a thick layer of 0.13-mm sand placed over the fixed bed and molded to any desired bathymetry, channel equilibrium areas were generated to determine the minimum cross section. Also, inner-bank erosion and the creation of an embayment behind the intersection of a jetty and the shoreline have been examined, as seen in Figure 3. Direction of sand spit development and encroachment on a channel was studied generically.



Figure 3. Idealized inlet model with sand bed showing erosion at shoreline terminus of intersection of jetties with beach

Other possible experimental situations can include more detailed actual bathymetry of an inlet for examining the tendency of channel migration with a change in channel alignment structures. Johns Pass, Florida, and Grays Harbor, Washington, have been studied in the facility. Also, innovative ideas such as bendway weirs will be evaluated.

CONCLUSION:

A physical model facility has been made operational in the Coastal Inlets Research Program and is available for the study of inlet hydraulics and inlet sedimentation at the Coastal and Hydraulics Laboratory. Its configuration permits the expedient and economical examination of generic or site-specific problem areas in the entrance region of a coastal inlet.

ADDITIONAL INFORMATION:

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